
Thermal stability optimization of the ESRF nano hutch

R. Baker, P. Marion, L. Zhang, T. Marchial, P. Mackrill and F. Favier

Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e46
DOI: 10.1017/S2044820110000808, Published online: 15 December 2010

Diamond Light Source Proceedings, Vol 1, e46, page 1 of 4
MEDSI-6 2010

doi:10.1017/S2044820110000808

Contributed paper

Thermal stability optimization of the ESRF nano hutch

R. BAKER†, P. MARION, L. ZHANG, T. MARCHIAL, P. MACKRILL AND F. FAVIER

European Synchrotron Radiation Facility, 6 Rue Jules Horowitz, 38043 Grenoble CEDEX, France

(Received 1 July 2010; accepted 10 November 2010)

The ESRF upgrade programme includes a number of extended beamlines in which instrumentation stability, be it mechanical or thermal, will be of utmost importance. Significant efforts are being made at every stage of design to increase stiffness and minimize thermal drift, but a thermally stable environment would greatly facilitate instrument conception and enhance overall performance. A numerical model of the most stable existing ESRF experimental hutch is detailed. With the aim to enhance thermal performance of future 'nano hutches', several optimization studies, both spatial and transient, have been performed on this model. Results from these studies and associated recommendations for future nano hutch design improvements are presented.

1. Treating thermal instability

There are a number of methods of dealing with thermal instability. Perhaps the most obvious is to use low Coefficient of Thermal Expansion (CTE) materials such as Invar alloys or Zerodur. Practically speaking, however, other factors must also be considered, such as engineering and radiation properties, vacuum compatibility, material matching and of course, cost.

Solutions using a thermal design technique are possible, although applying this principle to complex mechanical assemblies is far from trivial and may become a handicap to freedom of design, imposing compromises in other domains such as minimizing mass, optimizing stiffness or reducing Abbe errors.

Closed-loop compensation has proven successful in some applications but becomes somewhat complex when the absolute position reference is the photon beam itself.

In an effort to relieve constraints on the above-mentioned techniques, we have investigated the possibility of improving thermal stability of the environment in ESRF experimental hutches.

† Email address for correspondence: baker@esrf.fr

2. Existing standard and high-stability hutch at the ESRF

To date, the best results have been obtained on the ID22-NI experimental hutch in which porous entrance ducts have been installed along both sides of the hutch, below the roof panels, improving air distribution. Extraction is ensured through perforated tiles in a raised floor and an entrance porch limits disturbance from the experimental hall when opening the door.

Although performance is improved by a factor of 5 over standard ESRF hutches, spatial gradients remain significant and thermal stability is still insufficient for the most crucial applications.

3. The numerical model

A complete numerical model of the ID22-NI hutch has been built, reproducing real conditions as accurately as possible.

Temperatures, atmospheric pressure, lighting and door state, human presence, electrical power consumption, air velocity and water valve states were continually recorded over a period of 2 years. This data, plus thermal properties of all main elements was included in the model. A sinusoidal temperature profile of ±1°C was applied to external walls, simulating the average experimental hall day/night cycle. Temperature and air flow evolution was then evaluated and results compared with previously collected data.

4. Improvement studies

Once the model was considered true to reality, static and transient studies were run, clearly identifying a number of drawbacks: 35 % of the total air flow is 'lost' through leaks, large variations in air flow leave uncontrolled areas and cause gradients, heat generated from electronics close to the sample position degrade stability, and sensitivity to outdoor weather conditions is too high.

By varying parameters in the model, an improved configuration was run, in which controlled air is injected through a central porous sleeve running the length of the hutch, placed above a textile membrane covering the entire roof area. Extraction at the four lower corners and directly above the electronics rack is ensured via adjustable ducts and leaks are limited to 10 %. All walls (except the hutch entrance door) and roof are insulated (50 mm Rockwool equivalent).

5. Results and conclusion

Results show a significant improvement in thermal stability – ±0.045°C over 24 h at sample position – and much lower gradients (see figures 1 and 2).

A small effect from the non-insulated entrance door can still be seen. Therefore, an additional iteration was run, in which a temperature profile of ±0.2°C in the entrance porch and a perfect temperature control loop were simulated. Theoretical stability down to 0.01°C seems possible.

Finally, in order to assess the impact of thermal insulation of the walls and roof, a concluding simulation was run, based on the best established configuration, but with the Rockwool removed. Results confirmed that this parameter has a significant influence on thermal stability.

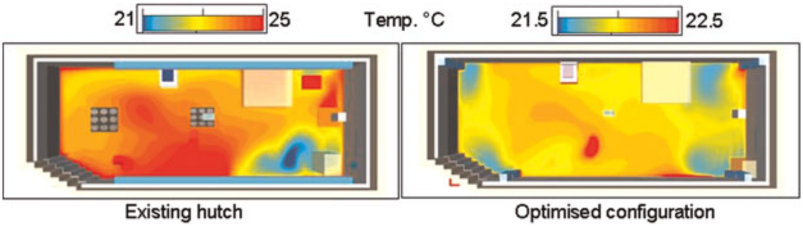

FIGURE 1. Top view of hutch showing spatial temperature gradient.

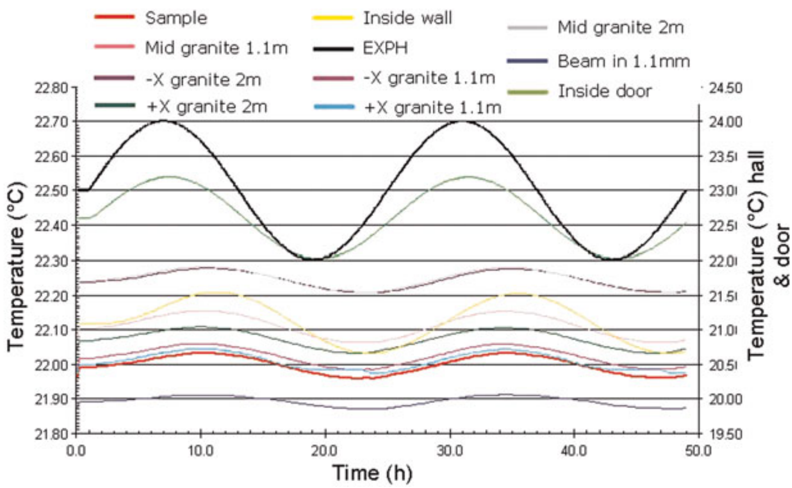

FIGURE 2. Improved simulation – temperature stability – 49 h at four points around sample position.

	Configuration	Gradient at sample (°C)	Overall gradient (°C)	Experimental hall temperature/hutch temperature (ratio)
1	Existing	0.67	5	3
2	Optimized ventilation and insulation	0.09	0.7	22
3	Temperature control in entrance porch and simulated regulation	0.01[a]	0.4	200[a]
4	Removal of insulation	0.46	3	4

TABLE 1. Temperature gradients and 'thermal independence' for the different configurations studied.
[a]theoretical

An estimation of the ‘thermal independence’ of the hutch can be obtained by comparing temperature change inside the hutch to temperature change in the experimental hall. Table 1 resumes this ratio and the gradients observed for the different configurations studied.

Clearly, configuration #3 gives optimistic results, as a perfect control loop is assumed. Nevertheless, we hope to obtain stability of a few hundredths of a degree at the sample position and an overall gradient well below 1°C. Recommendations from the best configuration (#3) have been included in the overall specifications for the construction of future ultra-high-stability hutches at the ESRF.